Journal of Forestry Research (2012) 23(3): 441-445
DOI 10.1007/s11676-012-0282-0

ORIGINAL PAPER

Seasonal effect on rooting behaviour of important bamboo species by culm cuttings

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Received: 2011-07-07 Accepted: 2012- 04-26

Abstract: We investigated the influence of season on the rooting behaviour of eight important bamboo species viz., *Bambusa balcooa*, *B. bambos*, *B. nutans*, *B. tulda*, *B. vulgaris*, *Dendrocalamus giganteus*, *D. hamiltonii* and *D. strictus*. We collected 2-3 node culm cuttings in three growing seasons viz. spring (March), summer (June) and rainy (August) from superior candidate plus clumps (CPCs) centralized in the germplasm garden. Cuttings were placed horizontally in sand and were provided with intermittent misting at regular intervals. Bamboo species exhibited differential rhizogenesis behavior in different seasons. The study reveals significant variation in sprouting and rooting behaviour in different bamboo species. *B. bambos* had maximum rooting (78.89%), followed by *B. vulgaris* (74.44%). In general, the potential of different bamboo species for rooting was found to be in the order: *B. bambos* > *B. vulgaris* > *B. balcooa* > *D. hamiltonii* > *B. tulda* > *D. strictus* > *D. giganteus* >*B. nutans*. The maximum rooting was recorded in spring (56.67%), which was closely followed by summer (54.58%). In winter season, minimum rooting (36.67%) was observed. The interaction effect of species × season was also significant on sprouting and rooting parameters. In *B. balcooa*, *B. nutans*, *B. vulgaris*, *D. hamiltonii* and *D. strictus*, cuttings collected in summer season showed maximum sprouting and rooting, whereas, *B. bambos*, *B. tulda* and *D. giganteus* had maximum rooting in spring. The maximum number of roots developed per cutting was observed in *B. tulda* (43.8) during spring season.

Keywords: bamboos, culm cutting, rooting, season, sprouting

Fouundation project: This work was supported by National Mission on Bamboo Applications (NMBA), Department of Science & Technology, New Delhi, India

The online version is available at http:// www.springerlink.com

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Responsible editor: Zhu Hong

Introduction

Bamboos, group of woody perennial evergreen plants, are considered to be the fastest growing plants in the world (Seethalakshmi et al. 1998). India is the second richest country in bamboo genetic resources after China. About 130 species are so far reported from India (Sharma 1987). The demand for bamboo has increased in recent years as a raw material for furniture making, panel boards, and for other uses. In India, the future plantation of bamboos will require over 70 million plants (Haridasan et al. 2008).

Conventional propagation of bamboo is based on seed and vegetative methods. However, the availability of bamboo seeds is limited due to a long flowering cycles. Even if seeds are available, they have low viability and poor storage characteristics. Further, species like *Bambusa vulgaris* and *Bambusa balcooa* flower rarely, thereby making their propagation absolutely dependent on vegetative means (Naithani et al. 1992; Banik 2000). Vegetatively, bamboos are propagated through clump divisions, rhizomes, offsets, layering, marcotting, culm cutting, branch cutting, macroproliferation and *in vitro* techniques. Propagation through clump divisions, rhizomes, offsets, layering and marcotting techniques limited number of plants and are not suitable for mass multiplication of bamboos. *In vitro* methods offer great scope but require higher initial cost of establishment of infrastructure and skilled workers.

Culm cuttings/branch cuttings offer effective, simple and useful solution for mass multiplication of bamboos (Banik 2008; Pattanaik 2004). However, bamboo species exhibit significant variations in the capability of adventitious rhizogenesis (Singh et al. 2006). Season or period of collection of cuttings also plays a major influence on the rooting (Dore 1953; Nanda et al. 1968; Hartmann et al. 1997). Nanda et al. (1975) attributed seasonal variations in rooting response to the changes in the relative/ absolute levels of endogenous rooting inhibitors and promoters.

Further, the effectiveness of even exogenously applied auxins is changed with the season and is also governed by morpho-physiological factors related to bud dormancy. Many studies regarding the role of season on rooting are available in dicot species, but relatively few studies are available in bamboo species (Agnihotri et al. 2000; Singh et al. 2004). The present study was undertaken to study the effect of season on rooting behaviour of eight important bamboo species with a view to develop comprehensive package for vegetative propagation.

Material and methods

The present investigations were conducted in the year 2008 in the nursery area of at the Agroforestry Research Centre of G.B. Pant University of Agriculture & Technology, Pantnagar, India. The experimental site is located in the *tarai* belt of Shiwalik range of Himalayan foothills between 29° 1′ 17″ N latitude and 79° 29′ 14 ″ E longitude at an altitude of 243.84 m above mean sea level. The climate of the region is broadly humid sub tropical with cool winter and hot dry summer. Generally, the monsoon starts in second fortnight of June and lasts up to September. The mean annual rainfall is 1,364 mm, of which 80%-90% is normally received in rainy season. The maximum daily temperature in summer may reach up to 45° C and minimum temperature in winter may fall up to 0.5° C. The weather parameters for the study period are illustrated in Fig. 1.

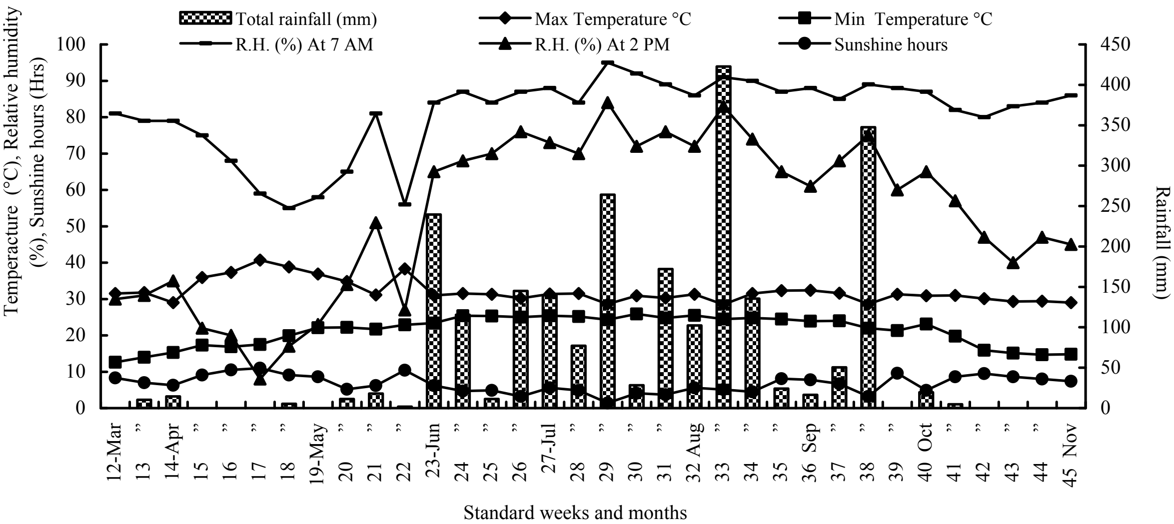

Fig. 1 Weekly weather condition during the study period

Eight economically important species, viz. *Bambusa balcooa* Roxb. (Bb) , *B. bambos* (L.) Voss (Bbm), *B. nutans* Wall. ex Munro. (Bn), *B. tulda* Roxb. (Bt), *B. vulgaris* Schrad. ex Wendl. (Bv), *Dendrocalamus. giganteus* Wall. ex Munro. (Dg), *D. hamiltonii* Nees and Arn. ex Murno. (Dh) and *D. strictus* (Roxb.) Nees (Ds) were selected for the present study. Culm cuttings were collected from the superior candidate plus clumps (CPCs) centralized in the germplasm garden. CPCs were based on phenotypic characters viz., height, diameter, length of internode and resistance to diseases and pests. The growth parameters of different bamboo species used during the study is given in Table 1.

Cuttings were collected in three different seasons viz. spring (15th March), summer (1st June) and rainy (1st August) from healthy growing clumps, which were free from insect pest and diseases. Culms were harvested at 50 cm above the ground, leaving 2-3 nodes to prevent any damage and infection to mother clump. Harvested culms were immediately transported to the nursery site. Each culm was then cut into sections, leaving 2-3 nodes on each section and retaining about 5 to 7 cm of culm portions at either end beyond the node. The leaves and side branches on each node were trimmed to length of 5-7 cm to avoid any injury to the buds. Nursery beds of 1.20-m width and 5-m length were made from three layers of bricks Sand was used as rooting media for filling the nursery beds.

Table 1. Growth parameters of different bamboo species used during the present study

Species	Culm height (m)	Culm diameter (cm)	Internodal length (cm)
Bambusa balcooa	16.7±1.04	9.57±0.60	25.5±0.49
Bambusa bambos	15.6±1.15	9.60±0.36	22.6±0.36
Bambusa nutans	14.5±0.50	7.73±0.68	35.5±0.49
Bambusa tulda	13.9±0.40	6.97±0.50	30.5±0.68
Bambusa vulgaris	16.2±00.87	8.87±0.35	30.7±0.64
Dendrocalamus giganteus	20.8±1.04	14.17±0.76	35.5±0.50
Dendrocalamus hamiltonii	12.7±0.70	9.20±0.53	22.7±0.68
Dendrocalamus strictus	10.3±0.85	6.43±0.40	26.5±0.81

Note: Values are mean ± standard deviation.

Interrnodal cavity of culm cuttings were filled with water by drilling a hole in the middle of the internodal cavity. The hole

was then covered with packing tape to avoid spilling of water from the internodal cavity. Culm cuttings were placed in the nursery beds at spacing of 20 cm horizontally in such a manner so that obliquely cut surface faces downward and the drill surface faces upward. The two sides of the hollow portion of the cutting were than filled with sand from both the ends. Cuttings were placed at 5-7 cm depth in the nursery beds and were covered with thin layer of fine sand. Cuttings were irrigated at regular intervals by intermittent misting. All the nursery beds were covered with agroshade nets of 50% transmission capacity to prevent drying of new sprouts from intense heat.

The experiment was laid out in Completely Randomized Factorial design (CRD) with three replications. Observations on sprouting rate, rooting rate, number of sprouts, number of roots, sprout and root length were recorded at the time of transplanting of the cuttings in poly bags. The data of each species were subjected to analysis of variance (ANOVA). The data on rooting and sprouting rate were converted to arc sine transformation ($\mathrm{Sin}^{-1}\sqrt{p}$) to normalize the data. However, other analyses were performed on untransformed data. Statistical analysis was carried out with the Statistical Package for Social Sciences (SPSS) windows software package using two factors, i.e., species and season. The mean values of each replication were estimated in the ANOVA-for studied parameters. For the comparison of different means in different treatments, the critical differences (CD) were calculated based on the Student *t*-test at the $p < 0.05$ level.

Results

The analysis of variance reveals that rooting and sprouting rates varied significantly due to species, season and interaction between the species and season (p<0.001) (Table 2). Different species were found to vary significantly in the rooting and sprouting behaviour (Table 3, Fig. 2 and 3). Maximum sprouting rate (80.00%) was observed in *Bambusa vulgaris*, which however was insignificant (78.89%) as compared to *B. bambos*. Rooting was maximum (78.89%) in *B. bambos*, which was statistically at par (74.44%) with *B. vulgaris*. Least rooting was observed in *B. nutans* (32.22%), which was at par with *Dendrocalamus giganteus* (33.33%) and *D. strictus* (36.67%). In general the potential of different bamboo species for rooting was found to be in the order of *B. bambos* > *B. vulgaris* > *B. balcooa* > *D. hamiltonii* > *B. tulda* > *D. strictus* > *D. giganteus* >*B. nutans*. Different species were also found to vary significantly in the sprouting and rooting parameters. Number of sprouts was maximum (3.13) in *B. vulgaris* (Fig. 2a). Sprout length was maximum (81.7 cm) in *B. balcooa* and minimum (42.73 cm) in *B. vulgaris* (Fig. 2b). Number of roots was maximum (35.65) in *B. tulda*, and minimum (5.79) in *D. strictus* (Fig. 3a). Root length was maximum (21.74 cm) in *B. balcooa* and minimum (5.90 cm) in *B. bambos* (Fig. 3b)

Table 2. Analysis of variance for sprouting and rooting behaviour from different species in different season

Source of variation	d.*f.*	Mean sum of squares					
		Sprouting	Number of sprouts	Sprout length	Rooting	Number of roots	Root length
Species	7	1302.40*	3.07*	2231.17*	1243.17*	668.19*	299.45*
Season	2	1577.27*	5.817*	2084.72*	1226.98*	203.16*	122.09*
Species × Season	14	213.93*	0.65*	157.784*	268.11*	135.64*	20.08*
Error	48	41.39	0.06	36.89	35.50	8.812	3.20
Critical difference at $p \leq 0.05$ level							
Species		6.09	0.22	7.86	5.65	2.81	1.69
Season		3.73	0.13	4.70	3.46	1.72	1.03
Species × Season		10.56	0.39	13.30	9.78	4.87	2.93

Note: * represents Significant at 1 % level of probability.

Table 3. Sprouting and rooting response in culm cuttings of different bamboo species

Species	Sprouting (%)				Rooting (%)			
	Spring	Summer	Rainy	Mean	Spring	Summer	Rainy	Mean
Bambusa balcooa	46.67 (42.99)	56.67 (48.84)	46.67 (43.07)	50.00 (44.97)	46.67 (42.99)	56.67 (48.84)	46.67 (43.07)	50.00 (44.97)
Bambusa bambos	93.33 (77.70)	86.67 (68.85)	56.67 (48.84)	78.89 (65.31)	93.33 (77.70)	86.67 (68.85)	56.67 (48.84)	78.89 (65.31)
Bambusa nutans	40.00 (39.23)	56.67 (48.84)	40.00 (39.14)	45.55 (42.40)	26.67 (30.07)	40.00 (39.14)	30.00 (33.21)	32.22 (34.38)
Bambusa tulda	50.00 (45.29)	66.67 (54.78)	50.00 (44.99)	55.55 (48.35)	46.67 (43.07)	43.33 (41.15)	40.00 (39.14)	43.33 (41.13)
Bambusa vulgaris	80.00 (63.92)	93.33 (77.70)	66.67 (54.78)	80.00 (65.47)	73.33 (59.00)	86.67 (68.85)	63.33 (52.77)	74.44 (60.21)
Dendrocalamus giganteus	53.33 (46.93)	13.33 (8.85)	13.33 (21.14)	26.67 (25.64)	73.33 (59.21)	13.33 (8.85)	13.33 (21.14)	33.33 (33.83)
Dendrocalamus hamiltonii	53.33 (46.93)	66.67 (54.78)	23.33 (28.78)	47.77 (43.49)	53.33 (46.92)	56.67 (48.84)	26.67 (30.99)	45.55 (42.25)
Dendrocalamus strictus	50.00 (44.91)	70.00 (56.99)	23.33 (28.78)	47.77(43.56)	40.00 (36.67)	53.33 (46.92)	16.67 (23.85)	36.67(36.61)
Mean	58.33 (50.98)	63.75 (52.45)	40.00 (38.69)		56.67 (49.84)	54.58 (46.43)	36.67 (36.63)	

Notes: Data within parenthesis represent arc sin transformed value.

Sprouting rate varied in different season, which was in order of summer season (63.75%).> spring (58.33%) >rainy (40.00%)

season (Table 3). Maximum rooting rate (56.67%) was recorded in spring which however, was insignificant as compared to summer (54.58%). Significant minimum rooting rate was in rainy season (36.67%). The highest values for number of sprouts (2.54), sprout length (57.11 cm), number of roots (25.74), root length (16.25 cm) were observed in spring season (Fig. 2a, b and 3a, b)

B. bambos in spring season showed maximum rate of sprouting (93.33%) and rooting (93.33%) while, *D. giganteus* in summer season produced minimum rate of sprouting (13.33%) and rooting (13.33 %). Interaction effect of species× season further revealed that the cuttings of *B. balcooa*, *B. nutans*, *B. vulgaris*, *D. hamiltonii* and *D. strictus* had maximum rate of sprouting and rooting in summer season, while *B bambos*, *B. tulda* and *D. giganteus* had maximum rooting rate in spring (Table 3). *B. balcooa* in spring season showed maximum sprout length (96.61 cm), whereas *B. tulda* in spring season had minimum sprout length (31.84), (Fig. 2b). Maximum number of roots (43.79) was produced in *B. tulda* in spring season, whereas minimum number of roots (4.72) was produced in *D. strictus* in spring season (Fig. 3a). *B. balcooa* in spring season also produced maximum root length (28.22 cm) whereas *D. giganteus* in spring season had minimum (3.16 cm) root length (Fig. 3b).

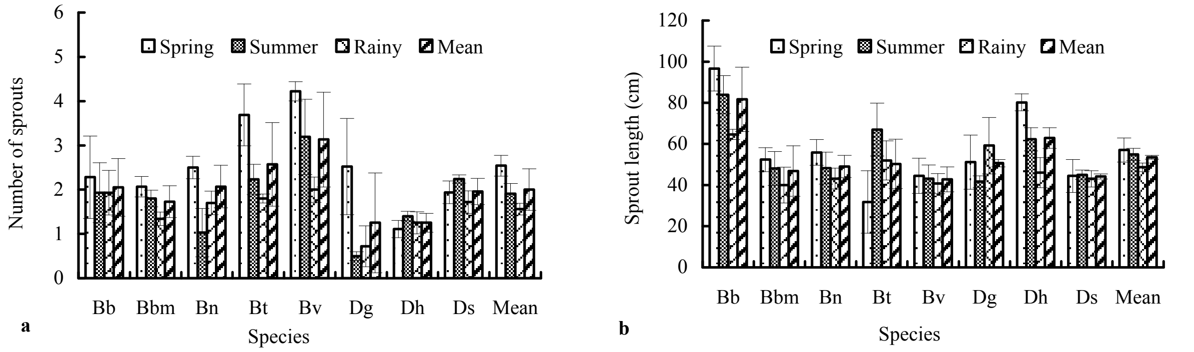

Fig. 2 Effect of species, season and their interaction on sprouting parameters

(Bb is *Bambusa balcooa*, Bbm is *B. bambos*, Bn is *B. nutans*, Bt is *B. tulda*, Bv is *B. vulgaris*, Dg is *Dendrocalamus. giganteus*, Dh is D. *hamiltonii*, Ds is *D. strictus*)

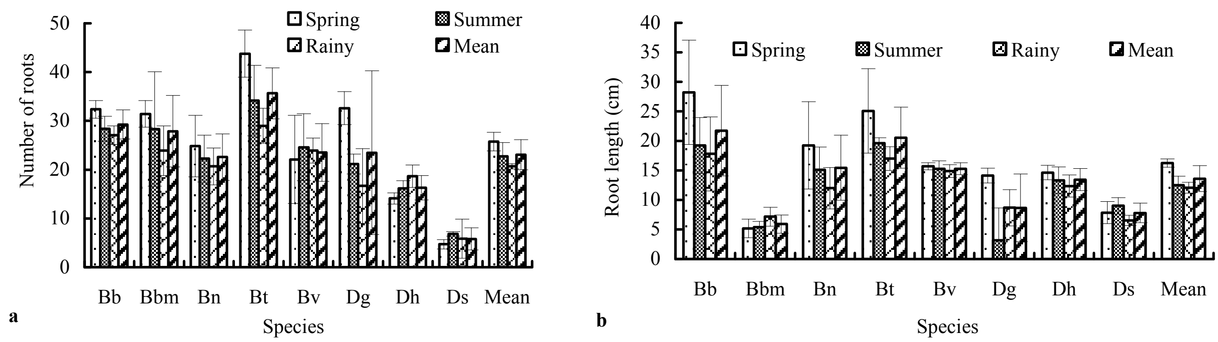

Fig. 3 Effect of species, season and their interaction on rooting parameters

(Bb is *Bambusa balcooa*, Bbm is *B. bambos*, Bn is *B. nutans*, Bt is *B. tulda*, Bv is *B. vulgaris*, Dg is *Dendrocalamus. giganteus*, Dh is D. *hamiltonii*, Ds is *D. strictus*)

Discussion

The analysis of variance reveals that the main effects of different seasons and species were highly significant (p < 0.001) on sprouting and rooting behaviour of cuttings. Maximum rate of sprouting and rooting was observed in *B. vulgaris* and *B bambos*. Sprouting and rooting behaviour of cuttings primarily depends on genotypic characteristics, environmental factors and/or the interaction between them (Dubey et al. 2008). Variation in sprouting and rooting behaviour in different bamboo species during the present study may be attributed to difference in genotypic characters (Saharia et al. 1990; Banik 1984). Poor rooting ability in *B. nutans* and *D. giganteus* was also reported in earlier studies (Gulabrao et al. 2011; Kaushal et al. 2009).

The findings also reveal that the rooting ability in bamboos is related to the time of collection of cutting (season). All the species showed a clear seasonal pattern, with significant higher ability of rooting and sprouting in summer and spring and than in rainy season. *B balcooa*, *B. nutans*, *B. tulda*, *B. vulgaris* and *D. strictus* resulted in higher sprouting and rooting percentage in summer season, while *B. bambos*, *B. tulda* and *D. giganteus* had maximum percentage of rooting in spring season. *D. hamiltonii* showed good rooting ability both in spring and summer season. Season plays an important role in the physiological state of the parent plant and the cuttings (Hartmann et al. 1997, Singh 2006). In north India, weather condition tends to moderate or shift towards warmness from February (spring season) after a dormant

period from October-January, which results in resumption of growth and upward mobilization of stored photosynthates and axillary substances from the underground rhizome and thus coincides with good rooting (Agnihotri et al. 2000; Singh et al. 2004, 2006). Further, in this study, higher rooting percentage in summer was attributed to higher temperature with high humidity as the cuttings were regularly irrigated. Agnihotri and Ansari (2000) also observed adventitious rhizogenesis in *B. vulgaris* and *D. strictus* during high temperature and long photoperiod. In present study, fungal infections were observed on *D. giganteus* which resulted in high mortality of the sprouts even after rooting of the cuttings. Kaushal and Tewari (2009) also reported poor survival rate of cuttings in *D. giganteus* due to fungal infection.

Conclusion

Bamboo species exhibit differential rhizogenesis behavior in different seasons. It is recommended that summer season is suitable for vegetative propagation of *B. balcooa*, *B. nutans*, *B. tulda*, *B. vulgaris* and *D. strictus*, while spring season is suitable for vegetative propagation of *B. bambos*, *B. tulda* and *D. giganteus*. *D. hamiltonii* can be propagated both in spring and summer seasons.

Acknowledgements

Thanks are due to Dr R.L. Banik, Scientific Advisor, NMBA for guidance and unstinted support during the study. We are also thankful to Dr N.M. Alam, Scientist Ag. Statistics, CSWCRTI, Dehradun for providing statistical help and to anonymous reviewers for critical comments and suggestions in the improvement of the manuscript.

References

Agnihotri K, Ansari SA. 2000. Adventitious rhizogenesis in relation to seasonal variation, size of culm branch cuttings and IAA treatment in bamboos. *Indian Forester*, **126**: 971-984.

Banik RL. 1984. Macro-propagation of bamboos by pre-rooted and pre-rhizomed branch cuttings. *Bano Biggyan Patrika*, **3**(1/2): 67-73.

Banik RL .2008. Issues in production of bamboo planting materials-lessons and strategies. *Indian Forester*, **134**(3): 291-304.

Banik RL. 2000. *Silviculture and Field Guide to Priority Bamboos of Bangladesh and South Asia*. Chittagong: Publication of Bangladesh Forest Research Institute, p. 187.

Dore J.1953. Seasonal variation in the regeneration of root cuttings. *Nature*, **172**: 189.

Dubey RM, Das PS, Choudhary Reetha. 2008. An investigation into macro-proliferation of some selected bamboo species of Assam. *Indian Forester*, **134**(3): 367-378.

Gulabrao YA, Kaushal R, Suresh NV, Verma A, Singh R. 2011. Effect of IBA on rooting of bamboo species. *Indian Journal of Ecology*, **38**: 227-228

Haridasan K, Tewari S. 2008. Bamboo for Pan India programmes-preliminary observations from recent trials. *Indian Forester*, **134**(3): 314-324.

Hartmann T, Kester D, Davies Robert L.1997. *Plant Propagation: Principles and Practices*. New Delhi: Hall Press, pp. 276-391.

Kaushal R, Gulabrao YA, Tewari SK, Chaturvedi S, Chaturvedi OP. 2011. Rooting behaviour and survival of bamboo species propagated through branch cuttings. *Indian Journal of Soil Conservation*, **39**(2): 171-175

Kaushal R, Tewari S. 2009. *Technology for Vegetative Propagation of Bamboos*. Research Bulletin No. 166. Uttarakhand, India. G.B. Pant University of Agriculture &Technology, p. 22.

Naithani HB, Biswas S. 1992. Gregarious flowering of *Dendrocalamus membranaceus*. *Indian Forester*, **118**: 300-301.

Nanda KK. 1975. Physiology of adventitious root formation. *Indian. Journal of Plant Physiology*, **18**: 80-89.

Nanda KK, Purohit AN, Adarsh Bala, Anand, VK .1968. Seasonal rooting response of stem cuttings of some forest tree species to auxins. *Indian Forester*, **94**: 154-162.

Pattanaik S, Das P, Borah E, Kaur, K. 2004. Vegetative multiplication of *Bambusa balcooa* Roxb. using branch cuttings. *Journal of Bamboo and Rattan*, **4**: 365-374.

Saharia UK, Sen SK. 1990. Optimum age bamboo culms for nodal cuttings. *Indian Forester*, **116**(10): 780-784.

Seethalakshmi, KK, Kumar MSM. 1998. *Bamboos of India*. Peechi, Kerala, India: Kerala Forest Research Institute, p. 342.

Sharma YML. 1987. Production and utilization of bamboos and related species in South Asia Region. *Indian Forester*, **114**(10): 603-609.

Singh S, Kumar P, Ansari SA. 2004. A simple method for large scale production of *Dendrocalamus asper. Scientia Horticulturae*, **100**: 251-255.

Singh S, Nain NPS, Meena SL, Tripathi SP. 2006. Patterns of adventitious root induction during different seasons in some bamboo species. *Journal of Bamboo and Rattan*, **5**(1&2): 89-95.